PHYSICS FOR GRAMMAR SCHOOLS

HARRINGTON

D. H. Shultz.

Tendency of matter to push & pull = force
Force is that which can produce, change or destroy motion

when forces act at insensible distances between molecules = molecular forces
when forces act between bodies at sensible distances they are called molar forces

PHYSICS

FOR GRAMMAR SCHOOLS

5719

BY

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NEW YORK ·:· CINCINNATI ·:· CHICAGO

AMERICAN BOOK COMPANY

HARRINGTON'S PHYSICS.
W. P. 2

PREFACE.

This book is the result of several years' use of the experimental method in teaching physics to boys under thirteen years of age. It considers subjects which are full of interest, and it compels the student to do work, to observe carefully, and to write an accurate account of his observations. In the case of every student it is found to awaken dormant energy and to arouse enthusiasm. After a lapse of three or four years, when the student begins the more earnest work of preparing for college science examinations, he finds himself acquainted with many fundamental facts and ready to advance rapidly.

The book, although preliminary, follows the method indicated in the requirements for admission to Harvard and Columbia Universities, and contains only such experiments as have been found by the writer to be serviceable.

The experiments set for the student should be performed at home, and notes of his observations should be written on slips of paper. During the recitation periods the results obtained by the several students should be compared and criticised, and the correct results then and there written in the blank spaces left for the purpose in this book. Two recitation periods per week for forty

weeks will be ample for performing in this manner all the experiments.

The experiments to be performed by the teacher should be closely observed by the students, and then *they* should state the correct results.

The writer hopes that his fellow-teachers will derive as much pleasure as he himself has obtained in watching the rapid growth of mental effort under this method of work.

C. L. HARRINGTON.

38 W. 59TH ST., NEW YORK.

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I.

MATTER—MASSES—MOLECULES—ATOMS—SPACES BETWEEN MOLECULES.

Experiment 1. Put as much water as possible into a goblet, and drop a stone gently into the water.

Exp. 2. Try to put any two objects into the same space at the same time.

Exp. 3. Push an inverted goblet into water, holding it firmly.

Why does not the water enter the goblet?

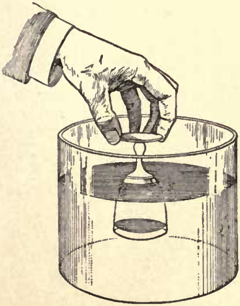


Fig. 1.

Suppose you have two things that can be handled; can you make either occupy the same space as the other at the same time?

Definition. — **Matter** is that which occupies space and prevents other matter from occupying the same space at the same time.

Exp. 4. Place in the sun's rays the goblet of water of Exp. 1.

Sunlight occupies space. Do you think from Exp. 4 that sunlight is matter?

Is all matter visible?

Name any invisible matter.

How many senses have we to help us in learning about matter? Give names.

Exp. 5. Break a lump of sugar into small pieces. Grind, or pound, some of these pieces into a fine powder. Dis-

solve some of this fine sugar in water. Can each particle of powdered sugar be seen with the naked eye?

Can the particles of dissolved sugar be seen, either with the naked eye or with a microscope?

NOTE. — These particles of dissolved sugar are the smallest possible particles of sugar; they are called **Molecules** of sugar. The chemist can obtain from these molecules particles smaller than the molecules, but these new particles will not resemble sugar in any respect; they are called **Atoms**. Thus molecules are made up of atoms.

Most scientists believe that nothing smaller than an atom exists.

Definitions. — A **Mass** is any appreciable quantity of matter.

Illustrations. ______

A **Molecule** of any mass is the smallest possible quantity of that mass.

Illustrations. ______

Exp. 6. Pour sand into a jar filled with marbles (or small stones) until no more sand will enter. Then pour in water until no more water will enter.

Why do not the marbles run over when sand is poured in? Why do not the marbles and sand run over when the water is poured in?

Because in the first case there are ....

....;

in the second case there are ....

....

Exp. 7. Slowly drop a little fine sugar into a cup as full of water as possible.

Why does not the water run over?

....

....

Exp. 8. Heat a tumbler of cold water by placing it in the sun's rays or *near* a stove.

Where have the air bubbles which appear been hiding?

....

....

Fig. 2.

Exp. 9. Half fill a *small* bottle, or test tube, with water; *carefully* pour in alcohol until the bottle is full. Close the mouth of the bottle with the thumb, and shake the bottle until water and alcohol are mixed.

Why is the bottle not full after alcohol and water are mixed?

We may now understand that there are spaces between the molecules of all kinds of matter.

II.

CONDITIONS OF MATTER—CHANGES IN MATTER.

Experiment 10. Try to separate the molecules of a piece of wood; of a piece of iron; of some water; of some mercury; of some air.

Definitions. — A **Solid** is a body whose molecules cling together with great force.

A **Liquid** is a body whose molecules cling together with little force.

A **Gas** is a body whose molecules do not cling together, but are all the time trying to get away from each other.

A **Vapor** is a gas which at ordinary temperatures changes either to a liquid or to a solid.

Name three solids.

Name three liquids.

Name three gases.

Name a vapor.

Name the three conditions of matter.

Exp. 11. Place a piece of ice in an iron spoon, and hold the spoon over a flame. Ascertain whether or not the ice can be changed into water, and the water into a vapor.

NOTE. — Hot (above 212° F.) vapor of water is called **steam**. Steam is invisible.

Warm (below 212° F.) and cold vapors of water are generally visible, and are called **clouds**, or **fogs**.

May iron, gold, wood, paper, and cloth be changed as the ice was changed?

Exp. 12. Move a book from place to place. What change is made?

What change was made in the sugar in Exp. 5?

What change was made in the ice in Exp. 11?

Name the three changes in matter.

Are the book, sugar, and ice of the same nature as they were before any change was made?

Definition. — Any change in a mass which does not involve change in the *nature* of the mass is called a **Physical Change.**

State several illustrations of physical changes.

Exp. 13. Experiment for the purpose of discovering any physical changes which have not been mentioned.

III.

SOME PHYSICAL PROPERTIES OF MATTER.

What is your property?

That which --

What is a property of matter?

That which --

Exp. 14. Repeat Exp. 7, and ascertain how much sugar can be added without making the water run over.

------------------------ teaspoonfuls.

Definition. — Porosity is that property of matter by which a body has pores; that is, spaces between its molecules.

Exp. 15. Hammer a piece of lead (or wood), and ascertain whether or not it becomes smaller.

Definition. — Compressibility is that property of matter by which a body may be compressed, or made to occupy less space.

Exp. 16. Obtain strips of rubber, wood, copper, iron, and zinc. Pull, or bend, these strips out of shape.

Definition. — **Flexibility** is that property of matter by which a body may be pulled, or bent, or twisted, out of shape.

Exp. 17. Repeat Exp. 16, and ascertain which of the bodies will resume their first forms after stress upon them is removed.

Definition. — **Elasticity** is that property of matter by which bodies tend to resume their first forms after being changed in form and after stress is removed.

Which of the bodies named in Exp. 16 are the most flexible?

Which are the most elastic?

Rubber is one of the most flexible substances known. Ivory and glass are among the most elastic substances.

Exp. 18. Obtain pieces of stone, glass, copper, and zinc. Try to scratch each with each of the others.

Definition. — **Hardness** is that property of matter by which some bodies may be made to easily scratch other bodies.

Exp. 19. Try to break pieces of glass, wood, copper, or zinc by striking them sharp, quick blows with a hammer.

Definition. — **Brittleness** is that property of matter by which some bodies may be easily broken by a sharp, quick blow.

Is hardness the same as brittleness?

Are all hard bodies brittle?

Are all brittle bodies hard?

Name six hard bodies which are not brittle.

Name six brittle bodies.

Name three properties of matter which belong to all bodies.

DEFINITION OF PHYSICS.

Physics treats of the laws, the physical changes, and the physical properties of matter.

SUMMARY OF FIRST THREE CHAPTERS.

Masses.	Three Conditions of Matter.
Molecules.	Three Physical Changes.
Atoms.	Some Properties of Matter.
Spaces between Molecules.	Physics Defined.

QUESTIONS IN REVIEW.

1. What is an experiment?
2. If a cubic inch of iron be put gently into a goblet full (to running over) of water, how much water will run over?
3. How might you find the size of your body?
4. Is an atom smaller than a molecule?
5. When a pin is pushed into putty, where does it go — through the molecules or between them?
6. When a nail is driven into wood, do the nail and wood occupy the same space at the same time? Explain your answer.
7. What is the ordinary condition of mercury?

8. How may one prove that steam is invisible?

9. Name some properties of whalebone; of ivory; of grass.

10. By reason of what property of matter are you able to bend leather? To press water from a sponge?

11. Is any property of matter illustrated by Exp. 3?

12. How would you prove that gold is softer than iron?

13. When a rubber cord is made longer by stretching, is the number of molecules increased?

14. If a quart of water be changed into steam, will the number of molecules of water be increased?

15. When a rubber ball is thrown against a wall, is the ball flattened?

16. By reason of what property is it flattened?

17. What causes the ball to rebound?

18. Is an ivory ball flattened when thrown against a hard substance?

19. When the wind blows hard against a large pane of glass, the glass is bent; why is it not broken?

20. Why does it flatten as soon as the wind stops blowing?

IV.

WORK — FORCE — GRAVITY.

Experiment 20. Try to move your open hand rapidly through some water in a tub.

Try in the same way to move an open fan (the flat side, not the edge) rapidly through the air.

Try to slide on a stone walk.

Why cannot these things be easily done?

Because in each case --

NOTE. — Our ideas of work are derived from the actions of our muscles. In the three cases just mentioned our muscles were at work, and they met with some resistance in doing the work. It is evident that the amount of work varies as the resistance varies: a large resistance calls for a large amount of work; a small resistance is overcome by a small amount of work. More work is done in sliding on a stone walk than in moving one's hand through water.

Definitions. — Work is the overcoming of resistance.
Force is that which does work.

What is motion?

What causes motion?

Exp. 21. Push a book; blow against some small pieces of loose paper.

What force causes the motions in this experiment?

What force causes molecules to get farther apart? (See Exp. 8.)

Name any other forces you think of.

Exp. 22. Suspend any object by means of a string held in the left hand. Cut the string with scissors.

NOTE. — Before the string was cut there seemed to be a pull *down*, caused by some force, and a pull *up*, caused by muscular force.

Now it has often been proved that *any two masses* attract each other.

Thus if two balls be prevented from falling to the earth, their mutual attraction may be made visible; and the larger the masses, the greater their mutual attraction. Two large masses of lead, when suspended by long, fine wires, will swing toward each other a little.

In our experiment (22) there was an attraction between the earth and the object; before the string was cut, our muscular force prevented their moving toward *each other.* After the string was cut, their mutual attraction caused the object to move toward the earth, and the earth to move toward the object.

Since, however, the object had a very small mass, and the earth a very large mass, the object moved many thousand times faster and farther than the earth.

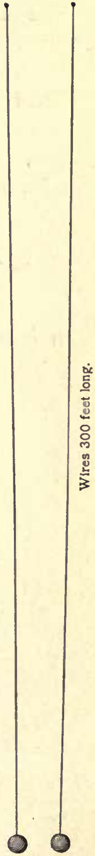
Definitions. — **Gravitation** is the force which causes masses of matter to attract each other.

This mutual attraction is called **Gravity** (for convenience) when the earth is one of the masses.

Weight is the measure of gravity.

NOTE. — It is evident that if gravity acts at a certain place with a force of one pound when an object has a certain mass, it will act with a force of two pounds on another object which has double the mass.

We must, however, distinguish between the names *mass* and *weight.*



Balls of lead each weighing one ton.
Fig. 3.

The mass of any object remaining the same, its weight will vary according to its place on the earth — the nearer it is to the center of the earth, the more it will weigh.

The North Pole being nearer the center of the earth than is the equator, any mass weighs more at the North Pole. Again, any mass weighs less at the top of a mountain than at the level of the sea or at the foot of the mountain.

When a ball is batted up, why does it not continue to move up?

If gravity were half as strong as it is, how high could you jump?

Give a reason for your last answer.

On what does the velocity (rate of motion) of a batted ball depend?

In what direction does a body move when acted on by a force?

Exp. 23. Suspend a pencil by means of a thread or string, and ascertain to what place the thread points when not swinging.

Definition. — A **Plumb Line** is a straight line that points toward the center of the earth.

What workmen use plumb lines, and for what purpose?

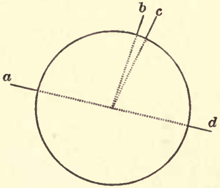


Fig. 4.
a, *b*, *c*, and *d* represent plumb lines at different places on the earth.

It is evident that plumb lines are not exactly parallel, since each points towards the earth's center. This makes no practical difference when the plumb lines are not very far apart. In the latter case, plumb lines are not perceptibly nearer together at their lower than at their upper ends.

V.

CENTER OF GRAVITY—FALLING BODIES.

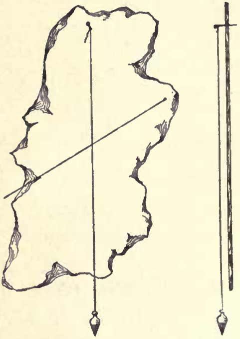


Fig. 5.

Experiment 24. Obtain an irregular piece of cardboard. After making two pin holes, as represented in the figure, suspend a plumb line from a pin stuck through one hole, and mark on the cardboard the direction of the line. Repeat, using the second hole. The two marks will cross. You will find that the cardboard may be balanced on the point where the marks cross.

Definition.—The **Center of Gravity** of a body is the point about which its molecules balance, no matter what the position of the body.

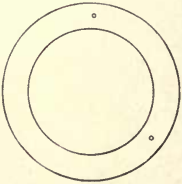


Fig. 6.

Exp. 25. Repeat Exp. 24, using a *ring* of cardboard.

The C. G. is not in the ....

....

....

Exp. 26. Stick a pin through a cork, and fasten two heavy sticks or knives into the sides of the cork (as in Fig. 7). Find the C. G. of the whole apparatus.

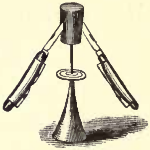


Fig. 7.

The C. G. is below the ....

....

How can it be shown that the ring of Exp. 25 may be balanced at its C. G.?

....

....

....

....

Draw a figure to show in what line the C. G. of a chalk box will move when the box is tipped a *little* upon an edge (*ab*); also when tipped over. Also to show in what line the C. G. of a pencil moves when the pencil is tipped over.

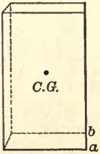


Fig. 8.

When is a body kept from tipping over?

Ans. When its C. G. is supported.

When is its C. G. supported?

Ans. When it is so placed that it cannot reach a lower position unless acted upon by some force other than gravity.

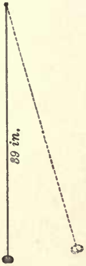

Fig. 9.

Why does a pencil standing on end continue to fall after being tipped a little?

If tipped, why will the object represented in Fig. 7 return to its upright position?

When is a body easily tipped over?

Ans. When, in the tipping, its C. G. needs to be raised but little.



Exp. 27. In some convenient place near a board (*ab*) slightly inclined, suspend a stone by means of a string 39 inches long. Set the stone swinging a little. Just as the stone begins one of its swings, let a marble begin to roll down the incline. Ascertain whether or not the marble will roll the same distance during the second as during the first swing.

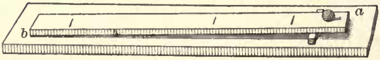


Fig. 10.

How many inches does the marble roll during the first swing? During the second swing? During the third swing?

1st .... 2d .... 3d ....

What force causes the marble to roll?

If the board were inclined more, would the marble roll faster?

In what position must the board be placed in order that the marble shall roll fastest?

In the last case the marble will fall freely, and the distance will be 16.08 feet during the first second.

Exp. 28. Drop a penny and a piece of paper side by side. Which falls the faster?

Exp. 29. Place a feather and a penny in a closed glass tube having a stopcock at one end. Exhaust the air, and let the two objects fall from one end of the tube to the other.

Fig. 11.

Why does the penny of Exp. 28 fall faster than the paper?

What force causes bodies to fall?

VI.

PENDULUMS.

Experiment 30. Using the stone and string of Fig. 10, let the stone swing through a distance of 6 inches. While it is swinging, learn the following definition:

Definition. — A **Pendulum** is a mass so suspended that it may swing freely to and fro.

When the stone (called the bob) is pulled to one side, what force causes it to swing back?

Why does it not stop swinging when it gets back to its lowest position?

Exp. 31. Count the number of vibrations (or swings) of your pendulum for one minute. Then make the vibrations 12 inches long instead of 6 inches, and ascertain if the number of vibrations is the same as at first.

Exp. 32. Make two pendulums of the same length, one having a bob of stone and the other of yarn. Do different materials affect the number of vibrations?

Exp. 33. Make two pendulums, one 10 inches long and one 40 inches long. Count the vibrations of each for one minute.

The first vibrates .... times.

The second vibrates .... times.

The length of a pendulum made of bob and string is (for the purposes of this book) the distance from the point of suspension of the string to the C. G. of the bob.

A pendulum must be 39.1 inches long in order to vibrate once a second at the sea level in New York City.

THE LAW OF THE PENDULUM.

The lengths of two pendulums are proportional to the squares of the times of their vibrations.

If two pendulums require 1 and 2 seconds, respectively, to vibrate, how long is the second pendulum compared with the first?

How many inches long is the second pendulum?

How long must a pendulum be in order to vibrate once in $\frac{1}{2}$ a second?

SUMMARY OF CHAPTERS IV., V., AND VI.

Work.	Center of Gravity.
Force.	Falling Bodies.
Gravity.	Pendulums.
Weight.	

QUESTIONS IN REVIEW.

1. Are molecules of ice smaller than those of water?
2. When is work done?
3. What is meant by resistance?
4. What work is done by heat in a steam engine?
5. What work do your muscles perform when you walk up a hill, or up stairs?
6. When is gravitation between two masses strongest?
7. If you were at the North Pole, would you weigh more or less than at present? Why?
8. If you rub two objects together, does your muscular force meet with resistance?
9. Define friction.
10. State the difference between the mass and the weight of a body.
11. Two objects are of the same size and shape; how may one find out whether or not they are of the same mass?
12. A falling body moves how far during the first second of its fall?

During the second second?

During the third second?

During the fourth second?

During the first two seconds? ------------------------------------

During the first three seconds? ----------------------------------

During the first four seconds? -----------------------------------

13. A clock in Washington, D.C., loses a very little time each day; to what place might the owner carry it so that it would keep correct time without being changed except in position?

14. What must be the length of a pendulum to beat once in three seconds?

15. Why should a body be at rest when its C. G. is supported?

16. Why do a penny and a feather, when in a vacuum, fall together?

----

17. In what direction does gravity act?

Ans. In a straight line connecting the C. G. of a body with the center of the earth.

18. What causes friction?

19. When is friction greatest?

20. Why are axles greased?

21. Can you mention any case in which friction is useful?

22. Name some force which acts at a distance. Illustrate.

23. Why are the legs of a chair farthest apart at their lower ends?

24. Why may a load of hay be easily tipped over?

25. Why is a man easily tipped over if his feet are near each other?

26. What is the only thing that affects the number of vibrations of a pendulum which is not moved from place to place on the earth?

27. Where will a pendulum vibrate the faster, at the North Pole or in Washington?

VII.

LEVER—WHEEL AND AXLE—PULLEY.

Experiment 34. With sugar tongs lift a lump of sugar. Cut some cloth with scissors. Notice a steam engine at work.

The tongs, scissors, and engine enable forces *to do work* easily and conveniently.

Definition.—A **Machine** is an instrument which enables forces to do work easily and conveniently.

Exp. 35. Obtain a stiff wooden stick about 1 foot long, 1 inch wide, and $\frac{1}{4}$ of an inch thick. Bore a small hole just over its C. G., as represented in the figure. Insert in the hole a short, stiff wire (to fit the hole tightly), and rest the ends of the wire on supports.

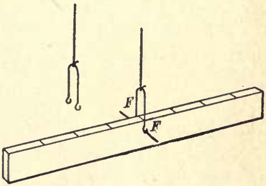


Fig. 12.

Explain why the bar remains in a horizontal position. (See Exp. 26.)

Definition.—A **Lever** is a stiff bar which can be moved about a fixed support called the *fulcrum* (*FF*, Fig. 12).

Exp. 36. Place a 5-cent piece on the lever, 5 inches from the fulcrum; find out how many similar coins must be placed at 5 inches from the fulcrum (on the other end of the lever) in order to balance the first coin; at $2\frac{1}{2}$ in.; $1\frac{1}{4}$ in.

1st .... 2d .... 3d ....

It is evident that the weight of the one 5-cent piece × 5 equals the weight of the two 5-cent pieces × $2\frac{1}{2}$, or the four 5-cent pieces × $1\frac{1}{4}$.

To use a lever, a certain intensity of force must be applied at one point in order to balance, or overcome, a resistance applied at some other point. In each case in Exp. 36, the pull of the coin (caused by gravity) on one side of the fulcrum was the force which balanced the resistance made by the pull of the coins on the other side.

Let F stand for force, R for resistance, and *fm* for fulcrum.

THE LAW OF THE LEVER.

The F × its distance from the fulcrum equals the R × its distance from the fulcrum when the lever is in equilibrium.

Relatively to F and R, there are three positions for the *fm*. Hence there are three kinds of levers:

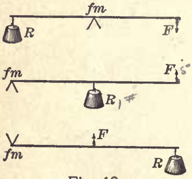


Fig. 13.

In the first kind the *fm* is between F and R.

(Resistance is sometimes called load.)

In the second kind R is between F and the *fm*, and F must act in a direction opposite to that of R.

In the third kind F is between R and the *fm*, and must act in a direction opposite to that of R.

The same law applies to all forms of levers.

Exp. 37. Experiment with a lever of the second kind. Keep the wire *fm* in the same place as at first, so that the weight of the wood on one side may balance that of the wood on the other side. Apply F by means of a spring balance, and make R 1 pound. Observe whether or not the results conform to the law.

This experiment may be repeated, using other resistances.

apply

Results. A F of ..5.. lb. at 5 in. balances a R of ..1.. lb. at $2\frac{1}{2}$ in.;

whence ...... $\times\ 5 =$ ...... $\times\ 2\frac{1}{2}$.

A F of ...... lb. at $4\frac{1}{2}$ in. balances a R of ...... lb. at 1 in.;

whence ...... $\times\ 4\frac{1}{2} =$ ...... $\times$ 1.

Exp. 38. Repeat Exp. 37, using a lever of the third kind.

Results. A F of ...... lb. at 2 in. balances a R of ...... lb. at 4 in.;

whence ...... $\times\ 2 =$ ...... $\times$ 4.

A F of ...... lb. at $1\frac{1}{2}$ in. balances a R of ...... lb. at $4\frac{1}{2}$ in.;

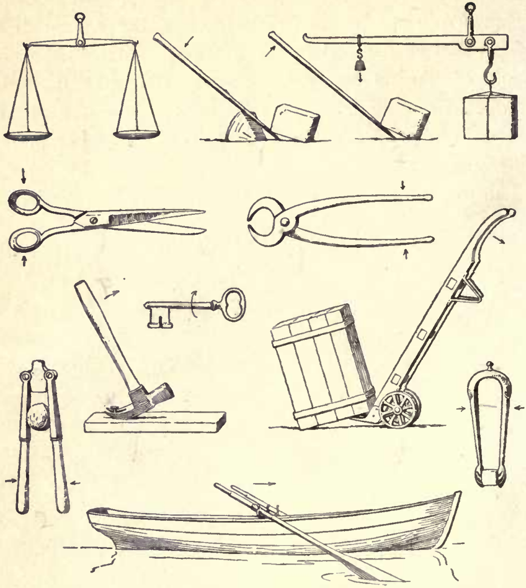
whence ...... $\times\ 1\frac{1}{2} =$ ...... $\times\ 4\frac{1}{2}$.

To which kind of levers does each of the following belong:

Scissors? .... Balance? .... Wheelbarrow? ....

Crowbar? .... Nutcracker? ...... Sugar tongs? ....

Forearm? .... Bootjack? .... An oar? ....1..........



Outlines of some common forms of levers. Arrows indicate directions of forces.
Fig. 14.

Exp. 39. Obtain a large spool, and by means of plugs fasten a stiff iron wire in position (Fig. 15). Bend one end of wire to form a crank. Rest this wire on two supports made of tin or wood, and tack these supports to a board. Wind a thread around the spool, and from the loose end suspend a weight of about 6 ounces. Suspend from the handle of the crank, kept in a horizontal position, a weight sufficient to keep the spool from turning.

Result. This weight is .... ounces.

Definition. — A **Wheel and Axle** is a machine in which a spool or spindle (called axle) is turned by means of a crank or wheel in order that a weight suspended from the axle may be lifted.

This machine is sometimes called a *windlass*.

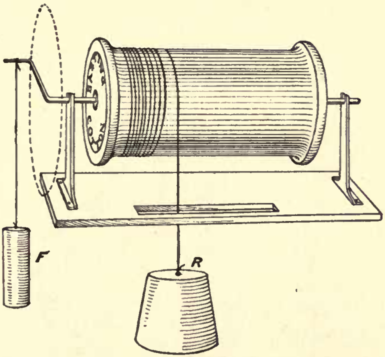


Fig. 15.

In the above machine, how does R compare with F?

Ans. R is ...... times as large as F.

How does the radius of the circle through which the F moves compare with the radius of the wheel?

Ans. It is ...... times as long.

LAW OF THE WHEEL AND AXLE.

F × the radius of the wheel equals R × the radius of the axle when the machine is in equilibrium.

Can you name any advantage one might gain in using a wheel and axle in lifting weights?

The capstan of a ship is of what value to the sailor?

Tell, if you can, how the wheel and axle is used in a derrick.

Exp. 40. Obtain two small clothesline pulleys. Suspend one of them from some firm support, pass the string over the wheel, and attach a known weight to one end of it. By means of a spring balance ascertain if anything has been gained by this machine.

No force has been gained;

but

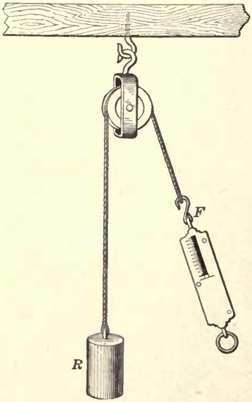


Fig. 16.

Definition. — A **Pulley** consists of a wheel and a block, the wheel being movable on a pivot in the block.

The pulley of Fig. 16 is called a *fixed pulley*, and is used in a great variety of ways.

Exp. 41. By means of a string, attach a spring balance to a board loaded to weigh about 6 pounds. Pull on the

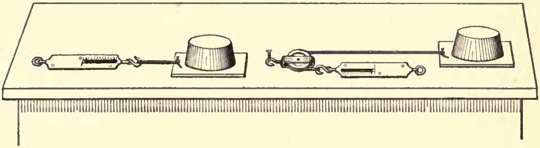


Fig. 17.

balance, and record the pull required to just move the board on the horizontal table.

Exp. 42. Pass the string around a fixed pulley, and pull on the balance in different directions with just force enough to move the board, as in Exp. 41.

What is gained by using a fixed pulley in this case?

Draw a picture to represent a method of lifting boxes to a height of two or three stories.

What is gained by using two fixed pulleys in this case?

Exp. 43. In Fig. 18 a fixed pulley (b) is used. There is also used a movable pulley (a). By means of a spring balance observe if any advantage, not found in the fixed pulley, can be found here.

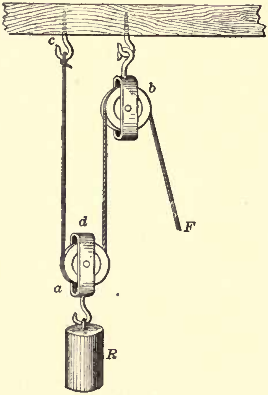


Fig. 18.

How large is F when R is 50 pounds?

How large is R when F is 100 pounds?

1st .... 2d ....

Do you think that by increasing the size of the wheel you would increase the advantage gained by using a movable pulley?

Draw a figure similar to Fig. 18, but putting the end of the cord marked c around a second fixed pulley, and attach it to the top of the block marked d. With such an arrangement, what is the relation of R to F?

Ans. R is ...... times F.

THE LAW OF THE PULLEY WHEN IN EQUILIBRIUM.

R equals F multiplied by the number of strings which hold R.

In lifting a load with the apparatus of Fig. 16, how fast does R move compared with F?

How would it be with the apparatus of Fig. 18?

In the case of the wheel and axle (Fig. 15), which moves the faster, R or F?

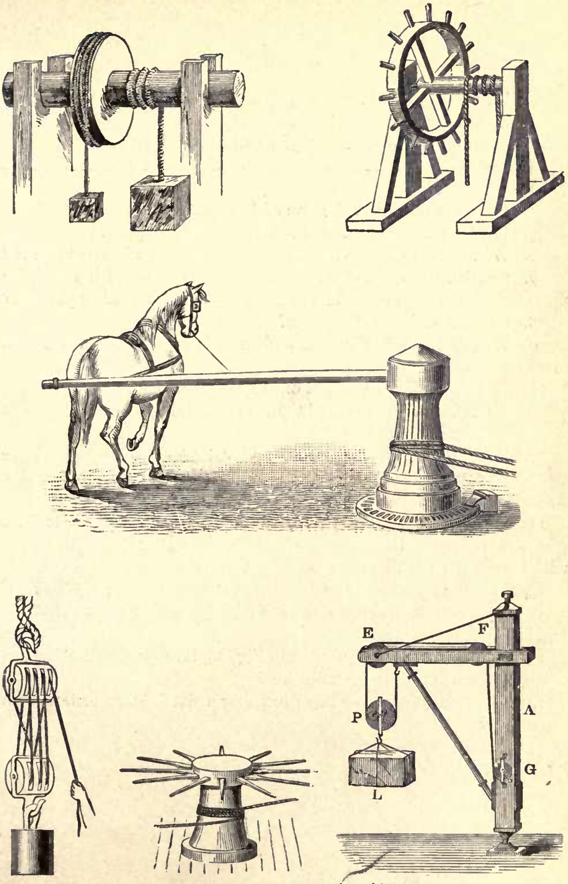
What is gained by using simple machines?

A small F ....

What is lost in using simple machines?
Ans. Time.

SUMMARY OF CHAPTER VII.

The Lever.
The Law of the Lever.
The Three Kinds of Levers.
The Wheel and Axle.
The Law of the Wheel and Axle.
The Pulley.
The Law of the Pulley.



Some practical applications of machines.

Fig. 19.

QUESTIONS IN REVIEW.

1. Why are the engines of a steamship placed as low as possible?

2. A man walking a tight rope generally carries a long curved pole loaded at the ends; what advantage in using such a pole?

3. How fast will a 28-inch pendulum swing when compared with a 7-inch pendulum?

4. Does any one know the size of a molecule?

5. Why are wheels used, and not runners, for wagons?

6. When will a lever of the first kind be balanced if R is twice F?

7. In what form of lever must I use a bar of wood if I wish by means of it to make a certain force balance as great a load as possible?

8. Can a machine create power?

9. Why is there loss of force when it is applied by means of a machine?

(It is evident that the weight of the movable pulley should be considered as a part of the load. In previous examples such weight has been left out of account.)

10. With the pulley of Fig. 18, how great a load could *you* balance by pulling down on the rope marked F, supposing the pulley a to weigh 10 pounds?

11. Suppose the movable pulley to weigh 2 pounds and F to be 2 pounds; what would happen if 2 pounds were attached to the movable block? if 1 pound were attached? 3 pounds?

12. May the wheel and axle be considered as one form of lever? If so, what represents the force arm? what the weight arm? what the fulcrum?

13. In the machine represented in Fig. 18, how far would F have to move in order to lift the load 2 inches?

14. What advantage is gained in using a fixed pulley instead of a round peg?

VIII.

ATMOSPHERIC PRESSURE—PRELIMINARY EXPERIMENTS.

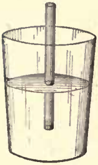


Fig. 20.

Experiment 44. Put one end of a small glass tube into water, and *then* close the upper end of the tube with the finger. Slowly lift the tube while the upper end is closed.

Fig. 21.

Exp. 45. Fill a tumbler with water, and place a piece of thick paper on the top. While holding the paper in place with the left hand, invert the tumbler with the right hand. After inversion, remove the left hand.

If the water should fall out, and no other matter should occupy the space in the tumbler, there would be a vacuum in the tumbler. Nature does not willingly consent to such an arrangement, and therefore provides means of keeping the water in the tumbler.

In Exps. 44 and 45, what holds the water in place?

Why is the paper needed in Exp. 45 and not in Exp. 44?

Why does a liquid flow from an inverted bottle in an unsteady stream?

Exp. 46. Punch a small hole in the bottom of a tin can (tomato or fruit can). Repeat Exp. 45, using the tin can, keeping the finger tightly pressed upon the hole.

After the can is inverted and the left hand has been removed from the paper, remove the finger from the hole.

In Exp. 46, why does the water fall after the finger has been removed?

What causes air to have weight?

Definition. — Pressure due to weight of air is called **Atmospheric Pressure**, and equals about 15 pounds per square inch.

If one end of the small tube (Exp. 44) be put into water, and some air be sucked out from the other end, water will rise to take the place of the air. The pressure of the outside air on the water of the jar forces water to rise into what would otherwise be a partial vacuum.

Draw a picture in explanation of the principle of the pneumatic inkstand.

IX.

ATMOSPHERIC PRESSURE—THE SIPHON.

Experiment 47. Bend a glass tube (see Appendix) to the shape of a U, but make one end a little longer than the other. Fill the tube with water and invert it, keeping the long arm closed with the finger. Place the short arm in a jar of water, and remove the finger from the long arm.

Fig. 22.

When the finger is on the open end of the long arm (before putting the siphon in water), why does not the water flow from the short arm?

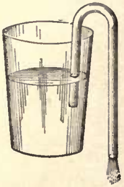


Fig. 23.

If the finger should be removed from the long arm before the siphon is placed in water, would the

water flow from the siphon? If so, from which arm, and why?

After the siphon is placed in the jar (Fig. 23), how long does water flow?

Exp. 48. Repeat Exp. 47, but putting the long arm in the jar of water.

How long does water flow from the outer arm?

What causes the siphon to operate?

Ans. The water in the long arm is heavier than that in the short arm; it therefore falls, and the water in the short arm follows, while air pressure on the water in the jar forces water up to take the place of the water which has been pulled over into the long arm.

The short arm is that portion of the tube between the bend and the surface of the water in the jar. That portion of the tube in the water is of use, however, because, as the level of the water is lowered, the short arm will have its end always in water. Of course the short arm is being lengthened as long as water flows through the siphon.

For what are siphons used?

What would be the effect of making a hole in the outer arm (Fig. 23) at the level of the water in the jar?

Find (in some geography) a picture of an intermittent spring, and explain the principle involved.

X.

ATMOSPHERIC PRESSURE—PUMPS FOR LIQUIDS.

Experiment 49. Fit a small glass tube (a) to a round cork which will plug the lower end of an argand lamp chimney. Cut a second piece of cork to such a size that while fitting closely it will move easily up and down in the chimney; then fasten a rod (R) to this cork. In each cork make a small hole, and cover each hole with a small piece of leather (thin), which should be held in place by a pin near the edge. You have now a **suction pump** consisting of a cylinder, a piston (P), a piston rod (R), and two valves—one at the bottom of the cylinder and one in the piston. A spout (b) may be fitted into a cork cover; the siphon tube may be used here.

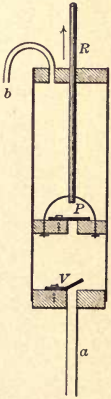


Fig. 24.

Definition.—A **Suction Pump** is a machine by means of which a liquid is drawn into a cylinder, and then lifted out of the cylinder through a spout.

Write a composition explaining the working of a suction pump.

THE SUCTION PUMP.

Exp. 50. Repeat Exp. 49, but put the spout at the bottom of the cylinder instead of at the top, and put the outlet valve in the spout instead of in the piston. This arrangement is called a *force pump.*

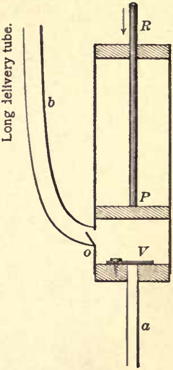


Fig. 25.

Definition. — A **Force Pump** is a machine by means of which a liquid is drawn into a cylinder, and then forced to a high level.

Write a composition explaining the working of a force pump.

THE FORCE PUMP.

In these pumps, why does water enter the cylinder through the valve *V* when the piston is moved up? (See note, p. 49.)

From what depth (below the piston) may water be raised by a suction pump?

Ans. From about 34 feet. This is because the weight of a vertical column of water 34 feet in length equals the weight of a column of air of the same size (not height). (See Definition, p. 49.)

To what height may water be forced by a force pump?

Force pumps are often worked by an engine instead of by hand.

A steam fire engine is no more nor less than a powerful force pump. The water drawn is either from an ordinary well or from a hydrant.

XI.

ATMOSPHERIC PRESSURE—PUMPS FOR GASES.

Definition. — The **Air Pump** is a machine for removing air (or other gas) from a jar.

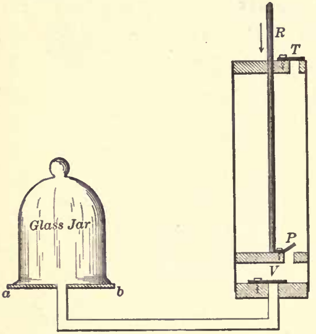


Fig. 26.

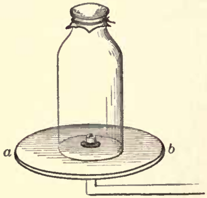


Fig. 27.

This pump is constructed like the suction pump for liquids, except that at the top of the cylinder it has a valve (T) instead of a spout.

Experiment 51. Place a hand glass on the pump plate, *ab*, having first tied a piece of sheet rubber over the smaller opening. Slowly work the pump handle.

Exp. 52. Repeat Exp. 51, placing the palm of the hand (instead of the sheet rubber) on the hand glass.

Fig. 28.

Exp. 53. Through the base of a long glass vessel pass a "fountain tube." Remove the air from the

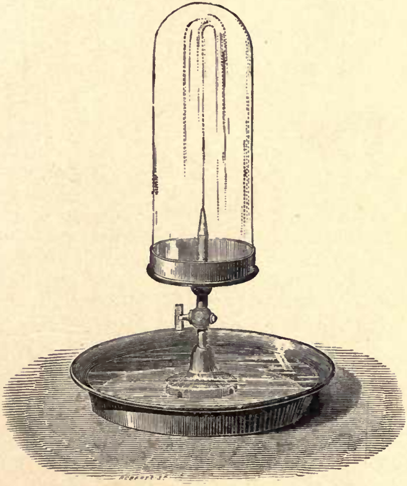


Fig. 29.

vessel, close the stopcock, put the lower end in water, and open the stopcock.

The vacuum fountain may be illustrated by filling a bottle with ammonia gas, inserting a fountain tube (glass) through a tightly fitting stopper, and inverting, so that the large end of the tube may be placed in water.

Fig. 30.

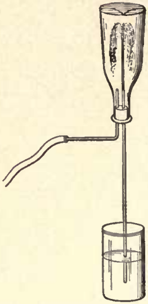


Fig. 31.

Or, by means of a second tube, air may be sucked out of the bottle while water rises in the fountain tube. The last method is the easiest, because neither air pump nor ammonia is required.

Exp. 54. Try to lift the glass jar of Fig. 26 from the pump plate after the air has been partly removed.

In Exp. 51, what caused the rubber to bulge into the jar?

In Exp. 52, what caused the hand to be held to the jar and the flesh to bulge in?

Explain the result of Exp. 53.

Why is it difficult to lift the jar of Exp. 54?

Write a composition explaining the working of an air pump.

THE AIR PUMP.

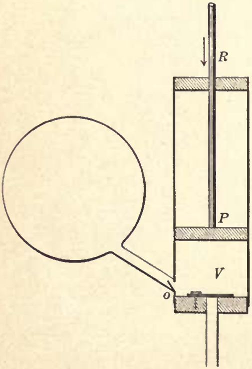


Fig. 32.

Definition.—The **Condenser** is a pump used for forcing a large amount of air (or other gas) into a small space. It is constructed like a force pump.

Write a composition explaining the working of a condenser.

THE CONDENSER.

Footballs are often filled by means of a condenser. The condenser is used also in inflating rubber tires of bicycles.

SUMMARY OF CHAPTERS VIII., IX., X., XI.

Atmospheric Pressure.	The Suction Pump.
Preliminary Experiments.	The Force Pump.
Amount of Pressure.	The Air Pump.
The Siphon.	The Condenser.

QUESTIONS IN REVIEW.

1. Where do we find air?
2. What is rare air?
3. What is dense air?
4. Why does an inflated balloon float in air?
5. What causes matter to move into vacuums?
6. What is a valve?
7. For what practical purpose is an air pump used?
8. For what practical purpose is a siphon used?
9. If in an air pump (Fig. 26) the cylinder holds one quart of air, and the glass jar holds one quart of air, how much air of ordinary density would you get out of the jar in once lifting the piston? In twice lifting the piston? In three times lifting the piston? How many times must the piston be lifted in order to pump out $\frac{31}{32}$ of the air in the jar?
10. Can *all* the air be pumped out of a jar?
11. With a condenser, how much air is forced into a holder at each stroke?
12. When the force arm of a lever is 10 inches long, and the load arm $2\frac{1}{2}$ inches long, how far must F move in order to lift R 1 inch?
13. What kind of a lever is each of the following:
    A door while being opened?
    A shovel used in throwing dirt?
    A shovel used in prying earth off a bank of hard earth?
14. If 40 pounds of direct pressure be required to crack a nut, how much pressure must be applied at the end of the handle of a nutcracker 6 inches long, the nut being placed 1 inch from the hinge?

XII.

MAGNETISM.

Experiment 55. Place a loadstone among some iron filings. Then lift the loadstone.

Exp. 56. Rub a piece of steel against a loadstone, and then place the steel against the filings. (A knitting needle will answer for this experiment.)

Definition. — A **Magnet** is something that will attract iron.

The loadstone (Exp. 55) is a *natural magnet*.

The steel (Exp. 56) is an *artificial magnet*.

Exp. 57. Ascertain whether or not the filings cling to the middle as well as to the ends of a magnet.

Exp. 58. Suspend your magnet by means of a fine silk thread (about 1 foot long); in what direction do its ends point after coming to rest?

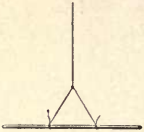


Fig. 33.

Exp. 59. After the magnet of Exp. 58 has come to rest, hold one end of a second magnet near one end of the suspended magnet; after the result is observed, hold it near the other end of the suspended magnet.

Exp. 60. Repeat Exp. 59, using second end of second magnet.

Definition. — The ends of a magnet are called its **Poles.** The end which points north when the magnet is suspended freely is called its **North Pole**, and the other end is called its **South Pole.**

Exp. 61. Suspend the second magnet, and see which end is its north pole and which its south pole. Then find out which ends of the two magnets attract, and which repel, each other.

NOTE. — When speaking of the direction in which a magnet points, the direction of pointing of its north pole is meant.

LAW OF MAGNETS.

Exp. 62. Break a magnet into two equal parts, and each of these parts into two equal parts, and ascertain whether or not each of the four pieces is a magnet.

Exp. 63. Wrap a magnet in a cloth, and observe its action on the poles of the suspended magnet.

Exp. 64. Repeat Exp. 63, using a bottle instead of cloth.

Exp. 65. Rub one end of a steel pen against a magnet. Test the pen for magnetism.

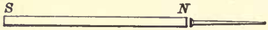


Fig. 34.

Exp. 66. Place a nail in contact with a magnet; does the nail become a magnet? If it becomes a magnet, does it remain so after contact is broken?

In Exp. 65, which end of the pen became north pole?

Ans. The end which was rubbed against the .... pole of the permanent magnet.

In Exp. 66, which end of the nail became south pole?

How is one end of a piece of steel made to have north polarity?

Out of what metal must permanent magnets be made?

Exp. 67. Suspend a small tack or pen from one pole of a permanent magnet, and then slide the opposite pole of a second magnet over the first one in the direction of the arrow.

Fig. 35.

Exp. 68. Over a large stationary bar magnet pass a small suspended magnet ($\frac{1}{2}$ inch long). Move it slowly

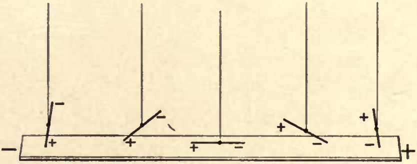


Fig. 36.

from end to end, and note the different directions in which it points. The magnets should not touch each

other. A short sewing needle magnetized will serve in this experiment.

A small magnet, so arranged that it may rotate freely, is called a **Magnetic Needle** (see Figs. 33 and 49).

If a magnetic needle be carried over the earth from pole to pole, it will stand almost vertically at either the North or South Pole, and will stand horizontally at the equator. Do you think from this that the earth is a magnet?

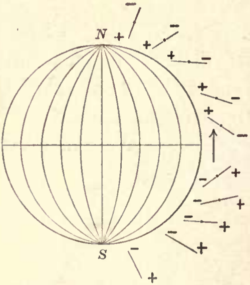


Fig. 37.

XIII.

FRICTIONAL ELECTRICITY.

The glass tube used in Exp. 44 may be used here.

The two pith balls must each be suspended by a fine, white silk thread (about 15 inches long), which should be tied to a wooden or a glass support.

The straw should be balanced as in Fig. 33.

See Appendix for further directions.

Experiment 69. Rub a stick of sealing wax with flannel, and bring it *near* (not touching) a pith ball.

It attracts

Then repells.

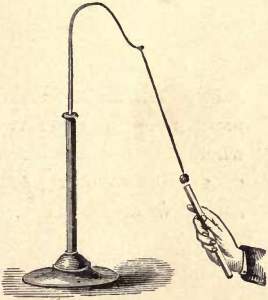


Fig. 38.

Exp. 70. Rub a warm glass rod with silk, and bring it *near* a pith ball.

Same

Exp. 71. Repeat Exps. 69 and 70, using the balanced straw instead of the pith ball. Suspending glass, it follows the rod.

Exp. 72. *Touch* each pith ball with the rubbed wax until it flies from the wax, and *then* bring the balls near each other.

repel

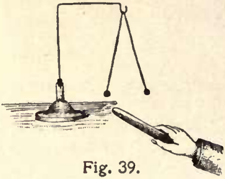


Fig. 39.

Exp. 73. Now touch each ball with the fingers, *then* touch one ball with the rubbed wax and the other with the rubbed rod, and bring them near each other.

attract

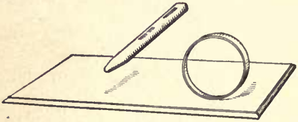


Fig. 40.

Exp. 74. Make a small paper hoop, and observe whether or not it will roll on a table following the rubbed wax.

yes

Exp. 75. Suspend the rubbed wax by a string, and bring your hand *near* the end of the wax.

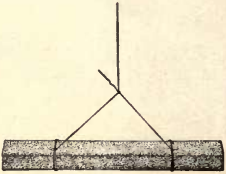


Fig. 41.

Exp. 76. Touch the pith balls, and then bring them near each other.

Exp. 77. Touch all parts of the rubbed wax, and then bring your hand *near* the end of the wax.

NOTE. — From the above experiments we learn that a body when rubbed by another body presents peculiar qualities. The body is said to be **Charged with Electricity**. A body is said to be **Discharged,** or **Neutral,** when it does not present these peculiar qualities.

Definitions. — From Exps. 72 and 73 we learn that there seem to be two kinds of electricity.

The kind that appears on glass rubbed with silk is called **Positive Electricity**.

The kind that appears on sealing wax rubbed with flannel is called **Negative Electricity**.

LAW OF ELECTRICITY.

NOTE. — Every object in its natural state is thought to hold both positive and negative electricity.

When an object is *said* to be charged with electricity, we understand that *in fact* one kind has been removed

and that the other kind has been left. For instance, we remove positive electricity from wax by rubbing the wax (Exp. 69) with flannel; we remove negative electricity from glass by rubbing the glass (Exp. 70) with silk.

When an uncharged pith ball is brought near charged wax (Exp. 69), the negative of the wax influences the *positive* of the ball to collect on that side next the wax, and drives the *negative* of the ball to the opposite side. The pith ball will therefore have one side charged with positive electricity and the other side charged with negative electricity. If the pith ball is allowed to *touch* the wax, the + on the ball will disappear, and the ball will be wholly −. Before contact the ball and wax attract each other; after contact they repel each other.

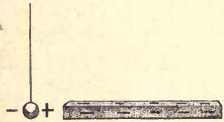


Fig. 42.

With which electricity is a pith ball charged after being brought in contact with a glass which has been rubbed with silk?

Why did the balls of Exp. 72 repel each other?

Why did the hoop of Exp. 74 follow the wax?

Exp. 78. Rub a piece of brass or iron rod with flannel; is any electricity shown?

Exp. 79. Repeat Exp. 78, after wrapping one end of the rod in white silk so that the brass cannot touch the hand.

NOTE. — In Exp. 79, the brass rod was insulated electrically by the white silk.

We learn from Exps. 69, 70, 78, and 79 that electrical qualities are shown by *any* substance that is rubbed. Some substances retain these qualities and others easily lose them.

Definitions. — A **Conductor** is a substance which cannot retain electrical qualities unless insulated.

A **Non-Conductor** is a substance which easily retains electrical qualities.

Exp. 80. Fill a tin plate (6 inches in diameter) with sealing wax, melting the wax into the plate over a stove (not too hot a stove, because the wax might take fire). To the middle of a blacking-box cover attach a glass handle (using wax). This instrument is called an **Electrophorus**, and is used for obtaining positive frictional electricity.

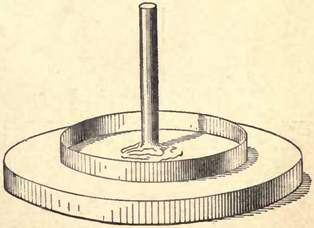


Fig. 43.

Exp. 81. Rub the wax with flannel, and put the cover on the wax (Fig. 43). Remove the cover by its handle, and test it for electricity. (Use pith ball charged with negative electricity for testing.)

Exp. 82. Repeat Exp. 81, but touch the cover with the finger just before removing it from the wax.

The figure in the margin represents the electrical condition of the parts of the electrophorus before the cover is touched by the finger.

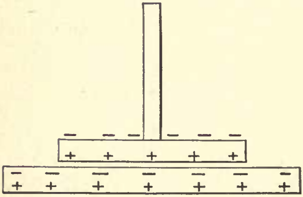


Fig. 44.

The finger allows the – of the cover to disappear; then, when the cover is lifted by its glass handle, it is found to be charged with + electricity.

If the tin plate be connected with the ground (through a chain attached to a gas pipe or water pipe), the charges on the cover will be more intense.

Exp. 83. Obtain a Leyden jar. Charge the cover of the electrophorus several times, bringing it each time

very near the ball of the Leyden jar. A small spark will be noticed at each operation. Shortly, the jar will be charged with positive electricity.

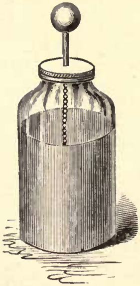


Fig. 45.

Now, holding the jar with one hand, bring a finger of the other hand near the knob.

Exp. 84. Rub a piece of ribbon with warm flannel, and hold it near the wall of a room.

Why were the balls of Exp. 72 first attracted and then repelled by the wax?

Why did they repel each other after being repelled by the wax?

How may a pith ball be charged and discharged?

Why should the pith ball be suspended by *silk* thread?

How may we know whether or not a body is charged?

How may we know whether or not a body is negatively charged?

SUMMARY OF CHAPTERS XII. AND XIII.

Magnets — Natural, Artificial, Poles of, and Law of.
Magnetic Induction in Soft Iron and in Steel.
Action of Large Magnet on Small Suspended Magnet.
Action of the Earth on a Magnet.
Developing Electricity on Wax and Glass.
Charging Pith Ball.
Kinds of Electricity.
Law of Electricity.
Theory of Electricity.
Conductors.
Non-Conductors.
Electrophorus.
Leyden Jar.

The following are experiments which may be performed in presence of the class, the teacher using a machine which will generate electricity in sufficient intensity.

Pith balls between metallic plates.
A pointed conductor near candle flame.
Charging a boy with electricity.
The electric whorl.
The aurora tube.
Electric bells.
The luminous pane.
The luminous tube.
Geissler tubes.
Discharging a Leyden jar through a line of boys.
Setting fire to ether or alcohol.
The electric seesaw.

Other experiments may be performed by the teacher if he has the requisite apparatus.

Large text-books on physics explain in full the experiments above indicated.

XIV.

CURRENT ELECTRICITY.

Experiment 85. Obtain a good pocket compass. Fasten two pieces of wood, *A* and *B*, to the ends of two thin pieces,

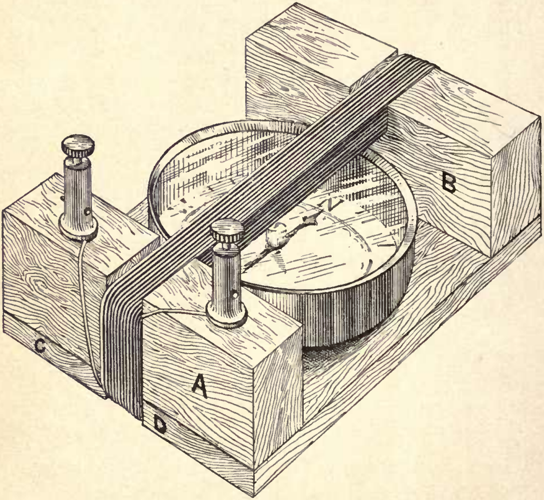


Fig. 46.

C and *D*. The distance between *A* and *B* should be about $\frac{1}{4}$ of an inch more than the diameter of the compass box.

The notches in the upper surfaces of *A* and *B* should be $\frac{1}{4}$ of an inch wide, and deep enough to admit 90 turns of No. 28 insulated copper wire. The wire should now be wound closely. When this is finished, the compass box should just fit in between the upper and under sets of wires. Two screw cups complete this instrument, which we will hereafter call a **Galvanoscope.**

The galvanoscope when in use should have its wires parallel to the north and south line.

Exp. 86. Attach a copper wire to a strip of copper (3 inches long, 1 inch wide), and one to a similar strip of zinc. Place the strips in a glass of water which contains a few drops of vinegar, and connect the ends of the wires with the screw cups of the galvanoscope. (The strips should not touch.)

Exp. 87. Repeat Exp. 86, using a few drops of sulphuric acid instead of vinegar.

NOTE.—This arrangement of acid, water, and two metals is called a **Cell.** The force that moves the needle

is called **Current Electricity**, and is developed by a chemical change in which the zinc is acted upon by the acid.

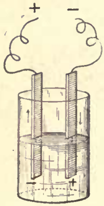


Fig. 47.

Since the zinc is active, it is called the **Positive Plate** of the cell. Since the copper is passive, it is called the **Negative Plate** of the cell.

The free ends of the wires which are attached to the plates are called **Electrodes.** The electrode of the zinc plate wire is negative, while that of the copper plate wire is positive. When the electrodes are put in contact, a current is said to flow in a complete circuit, and to move from the positive to the negative, as indicated in the figure.

PHENOMENA WITHIN THE CURRENT.

Exp. 88. Put one electrode against the under side of the tongue and the other against the top of the tongue.

Exp. 89. Hold one electrode in one hand and the other in the other hand.

(A battery of several cells will be required.)

Exp. 90. Insert a fine platinum wire (1 inch long) in the circuit of a two-cell battery.

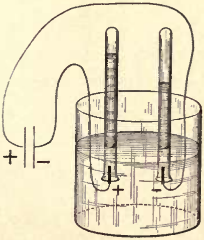


Fig. 48.

Exp. 91. Fill two test tubes with acidulated water, and invert them over flat platinum electrodes. (Melt some tallow or wax upon the portions of wire in the liquid, but leave the platinum strips uncovered.)

Exp. 92. Fasten a silver coin to the negative electrode, and place both electrodes in a solution of copper sulphate (bluestone).

NOTE.—The operation of Exp. 92 is called **Electroplating.**

PHENOMENA WITHOUT THE CURRENT.

Exp. 93. Pass a current from south to north over a magnetic needle.

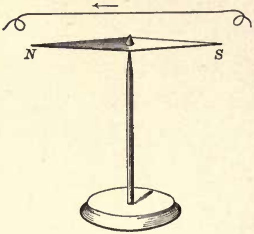


Fig. 49.

Exp. 94. Repeat Exp. 93, passing the current from north to south.

Exp. 95. Repeat Exps. 93 and 94, but pass the current under the needle.

Can you now explain the working of the galvanoscope of Exp. 85?

Exp. 96. Around a nail wind a few turns of insulated copper wire (No. 18). Put the wire in the circuit, and test the nail for magnetism; *i.e.*, bring one end of the nail near the poles of a needle, in turn.

Exp. 97. Remove the nail from the coil, and again test the nail for magnetism.

Exp. 98. Repeat Exps. 96 and 97, using a steel nail or wire.

NOTE. — A piece of soft iron surrounded by wire, as in Exp. 96, is called an **Electro-magnet**.

XV.

ELECTRICITY DEVELOPED BY MAGNETS AND BY CURRENTS.

Experiment 99. Make a helix (*ab*) by winding some insulated copper wire on a small round stick (or pencil), making the helix 3 or 4 inches long. Attach this helix to the binding posts of the galvanoscope. Then put a magnet with a quick motion into the helix, and watch the needle.

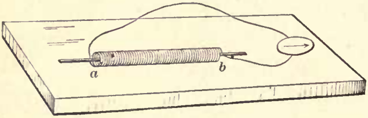


Fig. 50.

The galvanoscope in this and the following experiments must be placed 2 or 3 feet away from the helix, so as not to be influenced by *anything* except the current which is passing through it.

Exp. 100. Pull the magnet out quickly.

Exp. 101. Reverse the magnet, and repeat Exps. 99 and 100.

Exp. 102. On a bobbin about 2 inches long, wind 2 ounces of No. 32 double-covered copper wire. Around this helix of fine wire wind three or four layers of No. 18 cotton-covered wire. Connect the ends of the fine wire with the galvanoscope. Insert an iron nail in the center of the bobbin; then watch the needle as you connect the ends of the coarse wire with a battery.

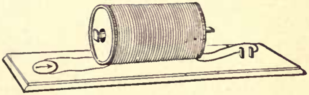


Fig. 51.

The wires should be wound neatly — as thread is wound on a spool.

Exp. 103. After the needle in Exp. 102 comes to rest, quickly break the battery circuit, and watch the needle.

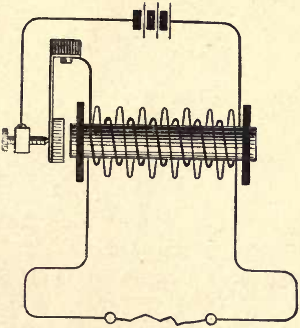
Exp. 104. Remove the nail from the helix, and repeat Exps. 102 and 103.

Exp. 105. Repeat Exp. 59, using the helix of Exp. 99 (connected with a battery) instead of the second magnet.

Is a helix through which a current is passing a magnet?

NOTE. — The last few experiments prove two things: first, that a coil (helix) through which a current is passing is a magnet; second, that a helix when surrounding a second helix, the ends of whose wires are joined together, causes a temporary current in the second helix each time the battery (or primary) current is made and each time it is broken. Notice also that these temporary currents alternate in direction, moving one way when the primary current is made and the other way when the primary current is broken. If the primary current be made and broken in rapid succession, there will be a rapid succession of temporary currents in the secondary coil. Thus we shall have in the secondary coil what is called an **Alternating Current** to distinguish it from the **Direct Current**, which is always the result of battery action.

Experiments 99–105 will enable even a young student to understand the construction and workings of Ruhmkorff's coil, the dynamo, the electric motor, and the telephone.



The Induction Coil in Section.

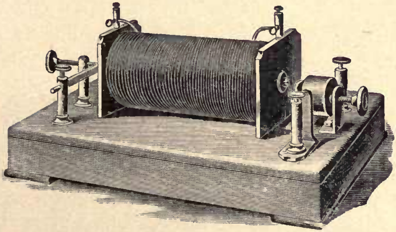


Fig. 52.—The Induction Coil.

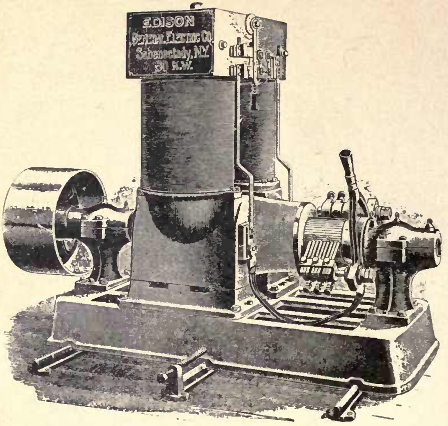


Fig. 53. — The Edison Dynamo.

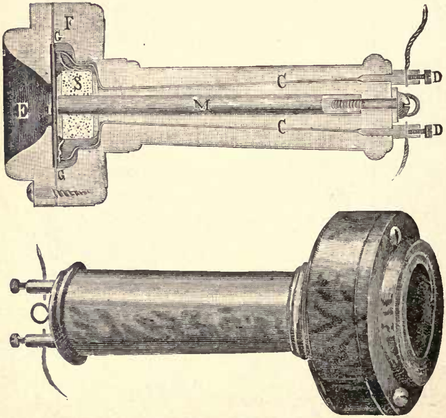


Fig. 54. — The Bell Telephone in Section and Perspective.

Exp. 106. Repeat Exp. 89, using the alternating current of Ruhmkorff's coil instead of the direct current of a battery.

Exp. 107. Repeat Exp. 91, using an alternating current.

Exp. 108. Pass an alternating current through a Geissler tube.

QUESTIONS.

1. May a helix be as good a magnet as a piece of steel?
2. In which direction does a battery current flow?
3. What effect is produced on a needle by changing the direction of the current which is passing over it?
4. What is an electro-magnet? (See Exp. 96.)
5. State some uses of an electro-magnet.
6. Name two ways of making a permanent magnet.

SUMMARY OF CHAPTERS XIV. AND XV.

Current Electricity.

The Current.
- Cells.

Phenomena within the Current.
- Water Decomposed.
- Electroplating.

Phenomena without the Current.
- Galvanoscope Explained.
- Electro-magnets.

Currents Developed by Magnets.

Induction Coil.

XVI.

MOVEMENT OF LIGHT.

Experiment 109. Make a large pin hole in each of three pieces of cardboard, and mount the boards so that the pin holes will be in a straight line. Place a flame opposite the first hole, and one eye opposite the last hole in such a position that the flame can be seen through the holes. Then move one of the boards until the holes are slightly out of line.

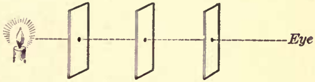
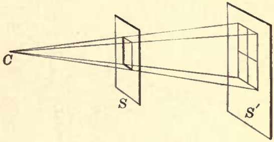


Fig. 55.

In what kind of lines does the light move?

Exp. 110. Cut a hole 1 inch square in a piece of cardboard; place the board upright and about 1 foot from a candle flame. Set a screen twice as far from the flame as is the hole (Fig. 56).



C, candle; *S*, screen containing square hole; *S′*, screen for image of hole.

Fig. 56.

The image of the hole is how large compared with the size of the hole?

How large would the image be if the screen were three times as far from the flame as is the hole?

If you were in a dark room, and should make a small hole through the wall, where would you place your eye in order to see the top of some object out of doors?

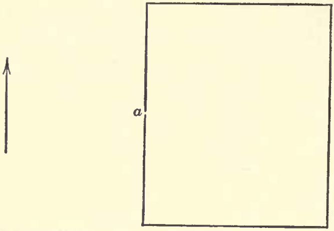


Fig. 57.

In order to see the bottom of the object?

In order to see that part of the object farthest to the right?

Farthest to the left?

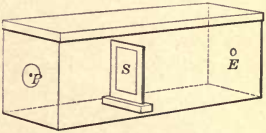
Light entering the room from an exterior object would form an image of the object on the wall opposite the hole. What can you say about such an image?

How far should the wall be from the hole in order that the image may be of the same size as the object?

If the image be 4 times as *broad* as the object, how far would the wall be from the hole?

If the image be 16 times as *large* as the object, how far would the wall be from the hole?

Exp. 111. Obtain a covered pasteboard box about 9 in. × 4 in. × 4 in. In one end bore a hole 1 inch in diameter, and cover the hole with a piece of thin leather, making a pin hole in the leather. At the other end make a small hole for observation. Put into the box a tissue-paper screen mounted on a movable block. Allow light from some object to pass through the pin hole, and move the screen until the image is distinct. This instrument is called the *pin-hole camera.* (Preserve this camera for a future experiment.)



P, pin hole; *S*, screen; *E*, eye hole.

Fig. 58.

When the image is 2 inches long and 5 inches from the pin hole, how far from the pin hole is the object which is 6 feet long?

________________ inches.

When an object is 100 times as *large* as its image, how far is it from the hole when the image is 8 inches from the hole?

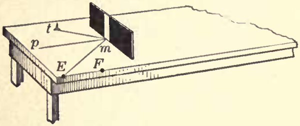
________________ inches.

REFLECTION OF LIGHT.

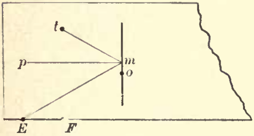
IMAGES IN MIRRORS.

By reflection of light is meant the rebounding of light.

Exp. 112. Draw, with crayon, a straight line upon a table; arrange a mirror perpendicular to the table and to the straight line, covering all but about ½ an inch of the mirror with paper, as indicated in the figure. Rest a tack on its head at some point, as at *t*, and move the eye along the edge of the table until the image of the tack can be seen in the mirror in the direction of *Em*. Draw lines from *E* and *t* to *m*. These lines represent the path of one of the rays of light which radiate from the tack. *tm* represents the **Incident**, or striking, ray, while *mE* represents the **Reflected** ray.



Side view.



Top view.

Fig. 59.

The angle formed by the incident ray and the perpendicular (*mp*) is called the **Angle of Incidence.** The angle formed by the reflected ray and the perpendicular is called the **Angle of Reflection.**

Do you notice any relation which exists between the angle of incidence and the angle of reflection?

Exp. 113. Repeat Exp. 112, after moving the tack out of the line *tm*. Do not erase any lines thus far made.

Exp. 114. Remove the paper from the mirror, and put the tack into its first position at *t*. Place the eye in a new position, as at *F*, and mark on the table the path of the ray by which you *now* observe the tack. At first you saw the tack in the direction *Em*, now you see it in the direction *Fo*. Remove the mirror, and see if you can decide where the image was.

Exp. 115. Repeat Exp. 114, after putting the tack in a new position.

How large are images which are seen in plane mirrors?

If you stand in front of a vertical mirror, how near the floor must the bottom of the mirror be in order that you may see the images of your feet?

REFRACTION OF LIGHT.

By refraction of light is meant the bending of a ray of light.

Exp. 116. Arrange a penny in an empty tin dish in such a position that it will be invisible to a person looking through a hole in a cardboard mounted near the dish (Fig. 60). Fill the dish with water, and again look through the hole.

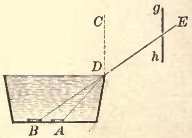


Fig. 60.

Only one (*AD*) of the many rays of light leaving the penny is represented. At what point is the ray bent?

Is the ray bent away from the perpendicular *DC*?

When you look at a fish in a pond, is the fish nearer to you than it seems?

You have observed that a ray of light moving from water to air is bent away from the perpendicular which is drawn to the surface of the water.

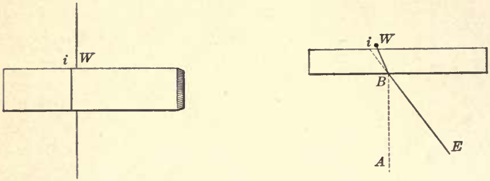
How would a ray be bent if it were moving from air into water?

Exp. 117. Place a piece of thick glass against a straight wire directly in front of the eye.

Does the wire appear straight?

Move the eye a little to the right; does the wire appear to be straight or to be broken?

The second drawing in Fig. 61 represents the glass and wire as seen from above. Explain how it is that the wire appears at *i* instead of at *W*.



Front view. Top view.

Fig. 61.

Exp. 118. Hold a pencil obliquely, and so that half is in water and half is out of water. Explain its appearance.

Exp. 119. Hold a burning glass so that the sun's rays may pass through it and fall upon a piece of paper.

Move the paper to and from the glass (which we will call a lens) until the image of the sun is as small as possible.

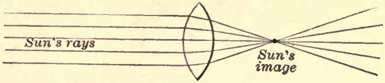


Fig. 62.

How many inches from the lens is this smallest image of the sun?

________________ inches.

Definition. — The point where the sun's rays meet after passing through a lens is called the **Focus** of the lens.

IMAGES FORMED BY A LENS.

Exp. 120. Hold a burning candle 4 or 5 feet in front of a lens, and catch its image on a paper screen.

Is the image as near the lens as is the focus?

What do you notice about the size of the image?

Move the flame to and from the lens until it is in such a position that the image is as large as the flame. Compare the distance of the object from the lens with the distance of the image from the lens.

How near the lens may you place the candle and still have a fairly good image?

Exp. 121. Hold the lens at arm's length, and look through it at some object 10 or 12 feet distant.

Exp. 122. Remove the piece of leather from the box of Exp. 111, and see if a good image of exterior objects can be caught on the screen in the box.

Exp. 123. Hold the lens so that it may take the place of the leather, and observe results as to size, clearness, position, and inversion of the image.

NOTE.—The box, as arranged with lens and screen, forms a good camera; by it one may illustrate some of the principles used in making photographs.

SUMMARY OF CHAPTER XVI.

Light.

- Moves in Straight Lines.
  - Images through a Small Hole.
- Reflection of Light.
  - Images in a Plane Mirror.
  - Angle of Incidence and Angle of Reflection.
- Refraction of Light.
  - By Mediums with Plane Surfaces.
  - By Lenses.
- Images formed by a Double Convex Lens.

XVII.

VIBRATIONS—SOUND.

Experiment 124. Stretch a string tightly between two fixed pegs about 3 feet apart. Pull the middle of the string a little to one side, and let go of it.

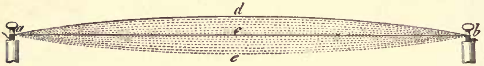


Fig. 63.

Result. (To eye and ear.) ....

....

....

The motions of the string to and fro are called **Vibrations.** It will be noticed that the molecules do not move lengthwise of, but only transverse to, the string.

Exp. 125. Obtain a goblet of *thin* glass, and rub its edge with your wet finger.

....

....

Exp. 126. Probably the vibrations of the glass cannot be seen. Therefore suspend a pith ball against the edge of the goblet while it is vibrating.

Fig. 64.

These and similar experiments indicate that sound is always the result of vibrations; and we believe that sound is caused by these vibrations. When the vibrating body moves forward it strikes the molecules of air,

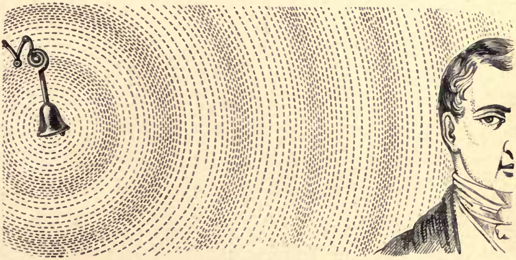


Fig. 65.

causing them to crowd together, and they in turn push against their neighbors, and so on. Thus a *condensation* is made to move outward in all directions from the vibrating body. This condensation of air molecules is followed by a *rarefaction* when the vibrating body moves backward.

One condensation and one rarefaction constitute a sound wave. These waves follow each other in rapid succession, and affect the drum of the ear, and we say that we hear a sound.

Exp. 127. Put your ear against one end of a log of wood while some one scratches the opposite end with a pin.

Exp. 128. Make a small hole in the bottom of each of two tin cans (mustard or pepper boxes). Obtain 10 or

The String Telephone.
Fig. 66.

12 yards of twine, pass one end through the hole of one can and the other end through the hole of the second can. Fasten a flat button (metal, ivory, or bone) to each end of the string. When the string is taut, conversation may be easily carried on through this string telephone.

A MEDIUM NECESSARY.

Exp. 129. By means of an iron rod passed through the rubber stopper of an air-pump receiver, suspend a vibrating bell in a vacuum.

Exp. 130. Allow air slowly to enter the receiver while keeping the bell in vibration.

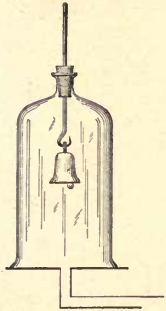


Fig. 67.

There are many experiments which indicate that in the absence of iron, wood, string, air, or some means of transmitting sound waves from a vibrating body to the ear, the ear is not affected, and no sound is heard.

RESONANCE.

Exp. 131. Fasten two triangular strips of wood (*a* and *b*) to a very thin board (Fig. 68). Stretch a string (or wire) tightly across these supports, and fasten it to small nails in the ends of the board. Repeat Exp. 124, using this apparatus.

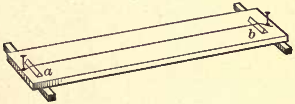


Fig. 68.

Exp. 132. Stopper the large end of an argand lamp chimney, and over the small end hold a vibrating tuning fork while slowly pouring in water.

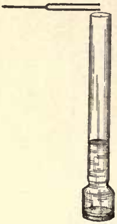


Fig. 69.

NOTE. — In Exp. 131, the small vibrating string sets the thin board into vibration. In Exp. 132, the small vibrating tuning fork sets the column of air in the chimney into vibration. In each case the increase in the intensity of sound is due to the vibrations of the increased amount of matter.

INTENSITY OF SOUND.

Exp. 133. Repeat Exp. 131, pulling the string at first only a little to one side, and then pulling the string considerably to one side. In each case notice the *intensity* (loudness) of sound.

NOTE. — Resonance causes intensity (or loudness) of sound. But intensity is more often due to the size of the vibrations. Thus if a violin player moves his bow across the strings with much vigor, the sound produced is loud mainly because the vibrations are large.

XVIII.

HEAT—EFFECTS OF HEAT.

Experiment 134. Fasten one end of an iron rod (about 2 feet long) on a box, and in such a manner that the other end shall rest against the upper part of a vertical lever. Heat the bar by means of an alcohol or a Bunsen flame.

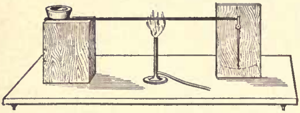


Fig. 70.

Exp. 135. Arrange a glass tube and a flask as in Fig. 71, putting in enough water to fill the bottle and a small part of the tube. Heat the flask gently over the Bunsen flame, and notice (by means of a paper index) any change.

Fig. 71.

Exp. 136. Through a rubber stopper fit a bent glass tube into the neck of a flask, and put the open end into a

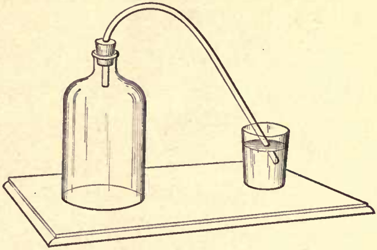


Fig. 72.

glass of water. Heat the flask by putting both hands on it.

Exp. 137. Apply heat to a piece of ice in a tin dish.

The heat changes the ice into water, and the water into steam. That is, heat changes the condition of matter. (See Exp. 11.)

What is one general effect of heat?

TRANSMISSION OF HEAT.

Exp. 138. Hold one end of a short iron wire, and dip the other end in a basin of boiling water; observe how many seconds elapse before the fingers feel the heat.

.... seconds.

Exp. 139. Repeat Exp. 138, using a wooden rod.

Exp. 140. Repeat Exp. 138, using a brass wire of the size and length of the iron wire.

In Exps. 138–140, those molecules of the rods which are in contact with the water become warm; without wandering from their places they conduct to their neighbors the heat received from the water. This method of transmission of heat is called **Conduction**.

Exp. 141. Put some bits of paper into a flask half full of water. Apply heat to the bottom of the flask.

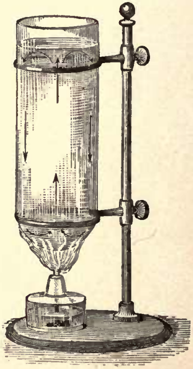


Fig. 73.

In this case the bits of paper show that there is molecular motion producing currents of water. The warmed molecules rise, thus actually transmitting heat by conveying it from the bottom to the top of the water; then, having given it up, they return for more.

All liquids and gases are heated by **Convection.**

Exp. 142. Stand a few feet from a fire; you will observe that, while you feel the heat, it reaches you neither by conduction nor convection, but seems to stream towards you.

Here heat is radiated by the fire. Heat is therefore said to be transmitted by **Radiation.**

Exp. 143. Into a test tube nearly filled with water put a piece of ice attached to a sinker. Apply heat near the top of the test tube until the water boils.

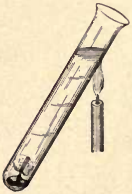


Fig. 74.

Is water a good conductor of heat? --------------------

EVAPORATION — DISTILLATION.

Exp. 144. Apply heat to the bottom of a test tube half filled with water. Dip the outer end of delivery tube

into water, and notice the bubbles which come out of the tube.

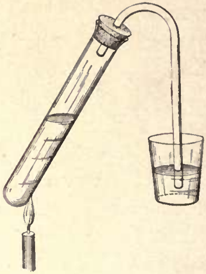


Fig. 75.

It will be noticed that in case of boiling, only the water comes out of the test tube. Any dirt or salt, or other impurity, is left behind in the test tube. This fact enables us to obtain pure water. The process is called **Distillation.**

Exp. 145. Arrange the delivery tube of a boiler in such a way that its outer end shall be in a Flor-

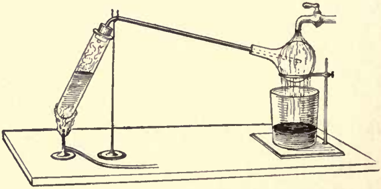


Fig. 76.

ence flask over which a stream of cold water is kept running.

SUMMARY OF CHAPTERS XVII. AND XVIII.

Sound.	**Heat.**
Vibrations.	Effects of Heat.
Of Strings.	On Solids.
Of Glasses.	On Liquids.
Theory of Sound Waves.	On Gases.
String Telephone.	Transmission of Heat.
A Medium Necessary.	Conduction.
Resonance.	Convection.
	Radiation.
	Evaporation — Distillation.

QUESTIONS IN REVIEW.

1. Which is the larger, an atom or a molecule?

2. Name the three conditions of matter.

3. Why does an ivory ball, when dropped on stone, rebound to almost the height from which it started?

4. Define work, force, and gravity.

5. What is a vapor?

6. Is paper flexible and elastic?

7. Where on the earth does matter weigh the most?

8. If a marble were dropped from the edge of a high roof, how far would it fall during the first second?

9. What would be true of a piece of paper under the same conditions?

10. A pendulum 9.775 inches long vibrates how many times per second at the sea level in New York City?

11. Account for the fact that a piece of iron is larger when warm than when cold.

12. A marble rolls down an incline 3 inches the first second; how far will it roll during the third second? During 3 seconds?

13. Is there a mass which has no elasticity?

14. A horse is moving a small house by means of four movable pulleys, and at the rate of 9 inches per second; how fast does the horse walk per minute?

15. The crank of a windlass is turned once a second; the circumference of the axle is $\frac{1}{5}$ that of the wheel, and a bucket of water is raised 1 foot per second; what is the circumference of the wheel?

16. Find the distance through which a stone falls in the eleventh second of its fall.

17. What do you understand by the mechanical advantage of a machine?

18. The weight at one end of a 6-foot lever in equilibrium is 200 pounds; the force is applied at the other end, and 2 feet from the fulcrum; how much is F?

19. Two men carry a 200-pound weight between them on a pole 5 feet long; one man carries only 80 pounds; how far from his hand is the weight suspended?

20. In a system containing three movable pulleys and three fixed pulleys, the movable pulleys weigh 6 pounds; what force must be applied to keep the system in equilibrium when no weight is suspended from the movable pulleys?

21. A force produces a motion of 14 feet per second in one mass, and 42 feet per second in another mass; compare the masses.

22. State some practical uses of the wheel and axle; of the pulley; of any combination of these two machines.

23. Suppose that the *F* and *R* represented in Fig. 18 (p. 43) are in equilibrium; how would you prevent motion if the *F* were increased by 2 pounds? If the *R* were increased by 2 pounds?

24. An egg floats on brine, but sinks in water; which has the greater S. G., the brine or the water?

25. In the siphon represented in Fig. 23 (p. 50), what would be the effect of lengthening the long arm?

26. What would happen if a hole were bored in the long arm of a siphon at a point above the level of the water in the jar?

27. What do you consider to be the short arm of a siphon?

28. How might you proceed to cover a brass spoon with a layer of silver?

29. How might you obtain hydrogen from water?

30. Draw a diagram to show the direction of flow of a current outside a cell, zinc and carbon being the elements of the cell.

31. When the needle is below a current and is deflected towards the west, what is the current direction?

32. Could a dry silk cord be used as a conductor for a battery?

33. How far from the aperture represented at *a* in Fig. 57 (p. 94) must an object be placed in order that the image may be three times the size of the object?

34. In looking into a room through a window pane, do we see objects in their real positions? Explain your answer.

35. What is the great source of light? Name two other sources of light.

36. Mention some musical instruments in which air is made resonant.

37. Does every vibrating body produce sound?

38. What causes a pendulum to vibrate?

39. How could you prove by means of a pendulum that gravity is greater at New York than at Panama?

40. How does rubbing a coin on a coat sleeve affect the temperature of the coin?

41. What is the great source of heat? Can you name two other sources?

42. In case light illuminates 1 square foot of surface when the surface is a short distance from the source of light, how much surface would the same number of rays illuminate at twice the distance? (See Fig. 56, p. 93.)

43. Suppose you were reading a book placed at a distance of 5 feet from a light; how many times brighter would the page be if you should place it $2\frac{1}{2}$ feet from the same light?

APPENDIX.

The teacher either should require the pupil to perform the following indicated experiments *in the schoolroom*, or should perform them himself before his class:

Exps. 9, 29, 36–38, 41, 42, 49–54, 80–83, 85–108, 112–115, 119–121, 123, 129, 130, 132, 134, 141, 143–145.

Exp. 16. Pupils should club together and buy, through the teacher, pieces of sheet lead, copper, iron, and zinc. These can be cut (with scissors) into strips about 2 inches long and $\frac{1}{2}$ an inch wide.

Exp. 37. The spring balance should weigh in $\frac{1}{4}$ pounds up to 8 pounds.

Exp. 40. The teacher should buy small swivel-tackle pulleys (30¢ per dozen).

Exp. 44. The teacher should buy glass tubing by the pound, allowing 1 pound for each 10 pupils. Tubing is sold in lengths of about 2 feet, *if so requested.*

One half the tubes (by number, not by weight) should be $\frac{3}{16}$ inch bore, and the other half should be $\frac{5}{16}$ inch bore.

Cut each tube into two equal parts, and allow each pupil one straight piece of $\frac{5}{16}$ inch, and one piece of $\frac{3}{16}$ inch bent into a siphon whose short arm is about 4 inches long.

Glass tubing is cut by making, at the place of cutting, a groove, using a three-cornered file. Then, holding the

tube in both hands, with the groove turned from the body, and holding the thumbs together behind the groove, push gently outward with the thumbs. File the sharp edges.

Fig. 77.

Glass tubing is bent by holding the tube in a jet of burning illuminating gas. Keep the tube rotating so that all portions of the part to be bent may be heated equally. When soft, bend tube quickly, and allow it to cool before removing the soot. If a gas jet is not convenient, use Bunsen or alcohol flame.

Exp. 49. It will be found much more satisfactory to buy glass models of pumps than to require each pupil to make his own. Glass pumps of German manufacture are sold at *very low* rates.

Exp. 51. No school should be without a good air pump and some attendant apparatus. Prices vary from about $15 up.

Exp. 56. Let the teacher buy large size knitting needles by the dozen, and magnetize them (four or five at a time)

by putting them into a helix about 7 or 8 inches long, made by winding heavy (No. 18) insulated wire closely around a lead pencil. Let the current pass on the helix wire for about a half a minute.

Exp. 59. Sealing wax should be bought by the pound in sticks about 8 inches long and ½ an inch square. Pith balls should be bought by the dozen. Straws should be bought by the package.

Exps. 80, 83. Pupils rarely succeed in making a satisfactory electrophorus or a Leyden jar.

Exp. 85. The pocket compass must be as sensitive as can be found. There is no gain in attempting experiments with a galvanoscope unless the needle be of the best workmanship. $1.25 should be the minimum price.

Exp. 90. Grenet cells will be found of more advantage than any other kind. Do not *require* pupils to make their own cells. The mixture for the Grenet cell consists of 10 parts (by weight) of sulphuric acid, 17 parts bichromate of

Fig. 78.

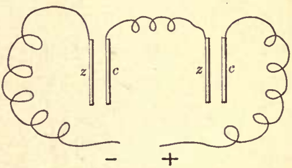


Fig. 79.

potash, and 100 parts water. The "American" Grenet is low in price ($1.25), and will last many years if

properly cared for. When using two or more cells, connect the zinc of one with the carbon of the second, etc. Always lift the zincs from the liquid when not in use.

The following lists comprise the most important pieces of apparatus required by pupil and teacher for use with this book. The things not indicated are too common to need naming.

FOR EACH PUPIL.

1 piece each of sheet lead, sheet copper, sheet iron, and sheet zinc (each piece 2 inches by $\frac{1}{4}$ inch).

2 pulleys.

1 foot glass tube, $\frac{3}{16}$ inch bore.

1 foot glass tube, $\frac{5}{16}$ inch bore.

1 piece sealing wax, 8 inches long, $\frac{1}{2}$ inch square.

2 pith balls.

2 straws, each 9 inches long.

2 knitting needles, No. 10.

FOR THE TEACHER.

1 convex lens, 2 inches in diameter.

1 alcohol lamp or Bunsen burner.

1 penny and feather tube.

1 spring balance, weighing to 8 pounds, and graduated in $\frac{1}{4}$ pounds.

1 glass suction pump.

1 glass force pump.

1 air pump with glass-stoppered receiver.

1 hand glass.

1 vacuum fountain.

12 rubber, or cork, stoppers, assorted sizes, — two holes in each if rubber.

1 small lodestone.

Catskin.

Electrophorus.

Leyden jar (3 pints).

Pocket compass.

1 pound No. 18 double cotton-covered copper wire.

2 ounces No. 32 double cotton-covered copper wire.

$\frac{1}{2}$ ounce No. 28 single silk-covered copper wire.

2 pounds sulphuric acid.

2 Grenet cells, "American."

6 five-inch test tubes.

$\frac{1}{2}$ pound copper sulphate.

1 pound bichromate of potassium.

Ruhmkorff's coil ($\frac{1}{4}$ inch spark).

Geissler tube.

2 twelve-ounce Florence flasks.

1 rat-tail file (6 inches long).

1 three-cornered file (6 inches long).

8 feet small brass chain.

Piece platinum foil, 1 inch by $\frac{1}{2}$ inch.

4 inches fine platinum wire.

2 wood-screw binding posts, single (smallest size), Exp. 85

Rubber tissue (6 inches square).

4 double connectors (plain).

Tuning fork (6-inch prongs).

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